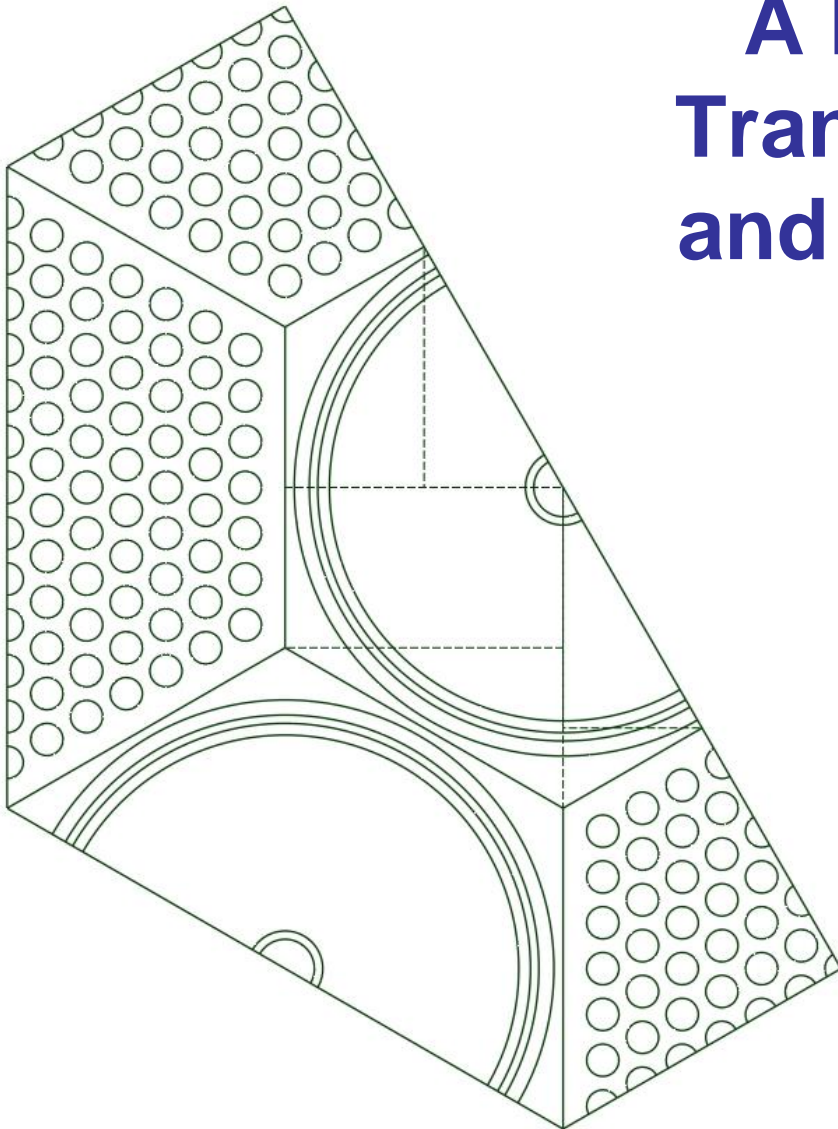


A Multi-Dimensional Heat Transfer Model of a Tie-Tube and Hexagonal Fuel Element for Nuclear Thermal Propulsion

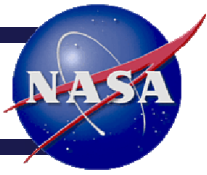
C.F Gomez, O.R Mireles, E Stewart

Presented By
Carlos Gomez





Outline



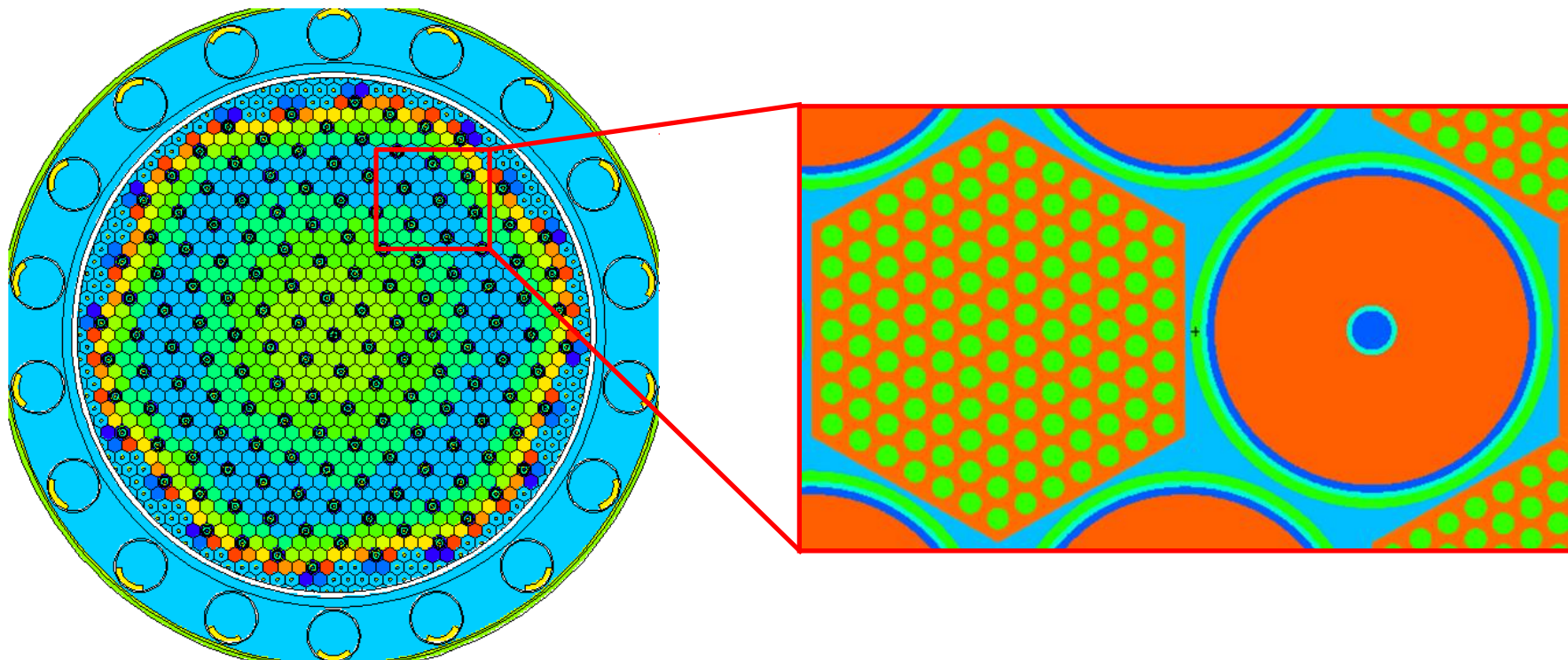
- The Space Capable Cryogenic Thermal Engine (SCCTE)
- Hex Fuel Rod Model
 - Results
- Tie Tube Model
 - Results
- Conclusion
- Future work

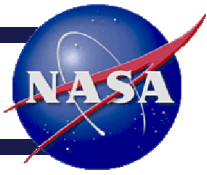


Nuclear Thermal Rockets



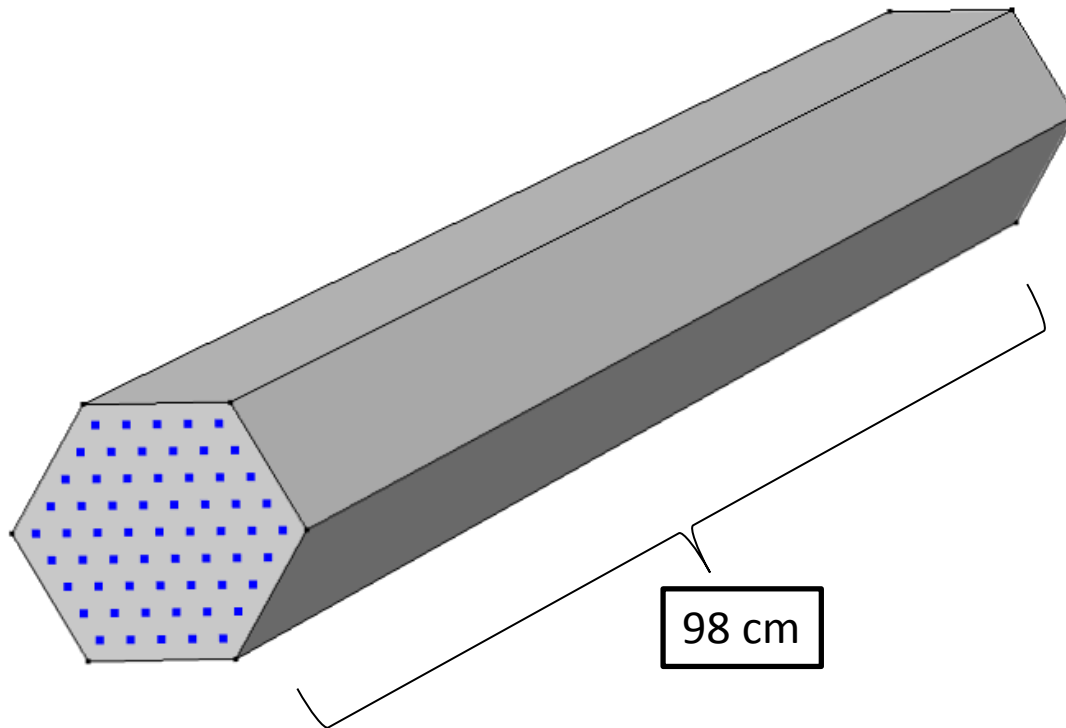
- The Space Capable Cryogenic Thermal Engine (SCCTE) effort considers a nuclear thermal rocket design based around a Low-Enriched Uranium (LEU) design fission reactor. The reactor core is comprised of bundled hexagonal fuel elements that directly heat hydrogen for expansion in a thrust chamber and hexagonal tie-tubes that house zirconium hydride moderator mass for the purpose of thermalizing fast neutrons resulting from fission events.





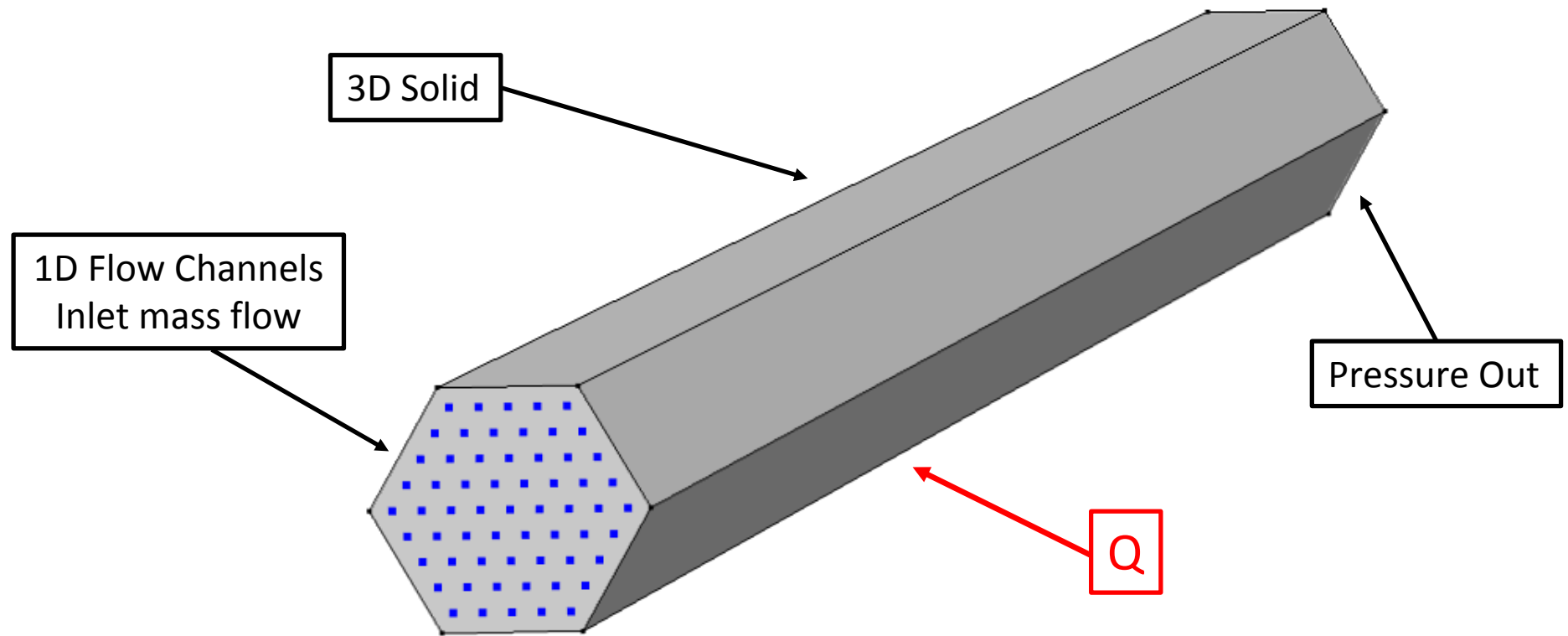
Hex Fuel Rod Design

- Created 3D steady state Hex fuel rod model with 1D flow channels
- Hand Calculation were used to set up initial conditions for fluid flow
- The Hex Fuel rod uses 1D flow paths to model the channels using empirical correlations for heat transfer in a pipe.



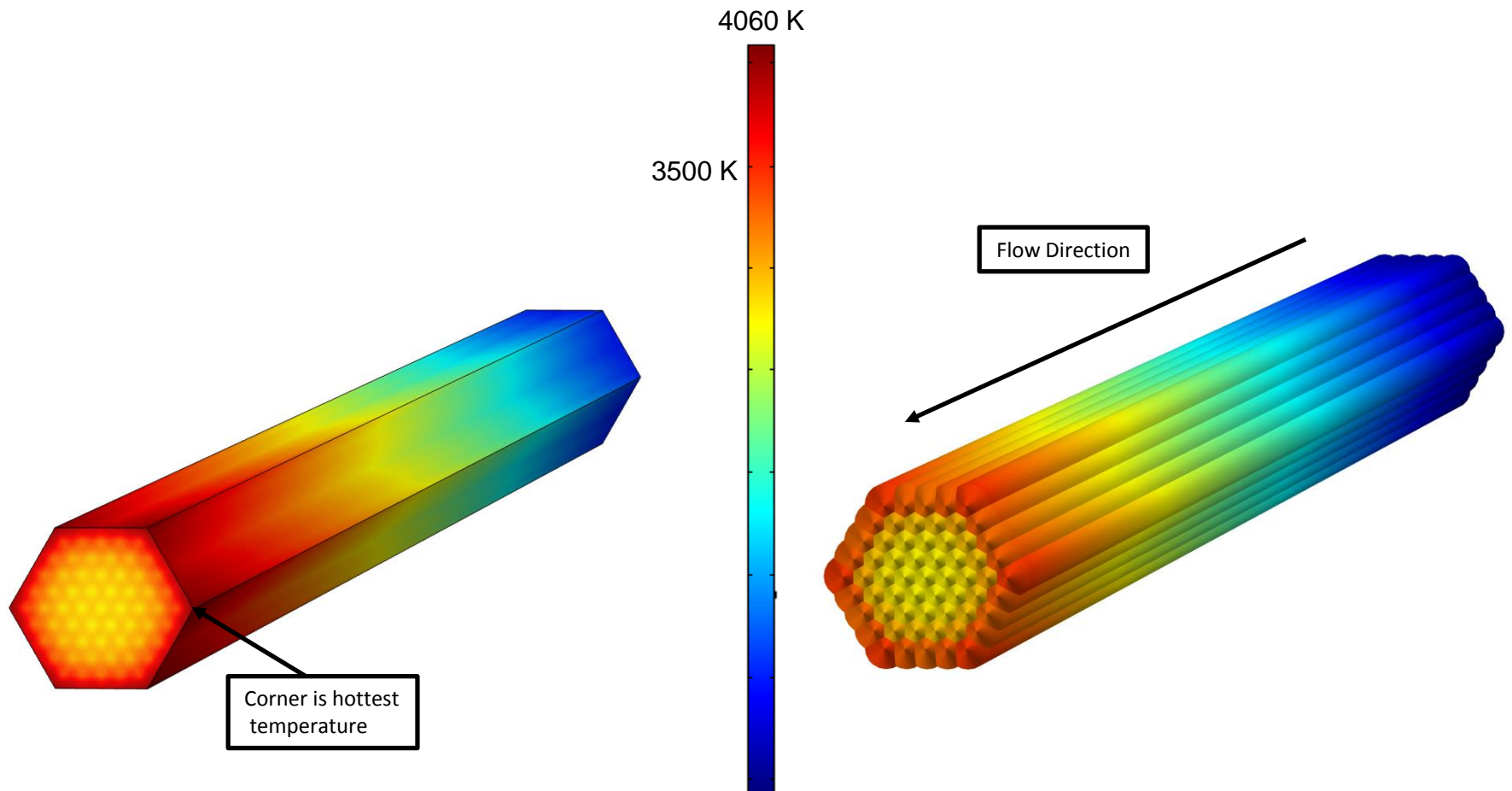


Hex Fuel Rod Model



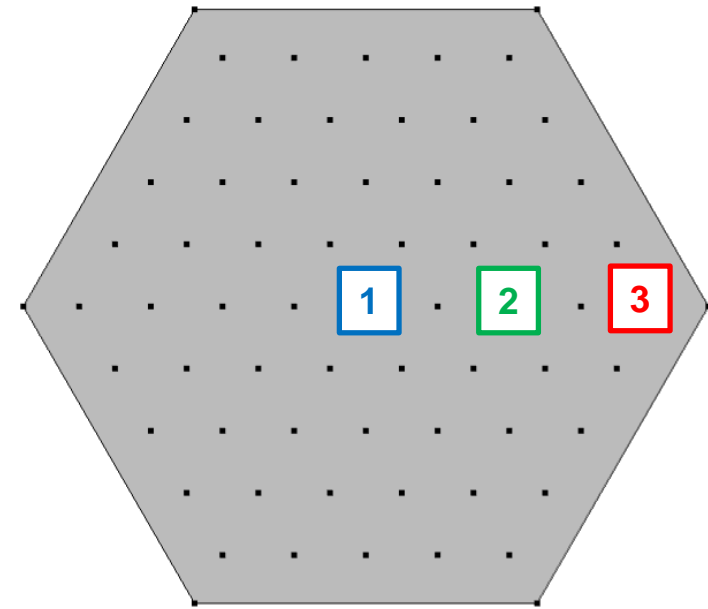
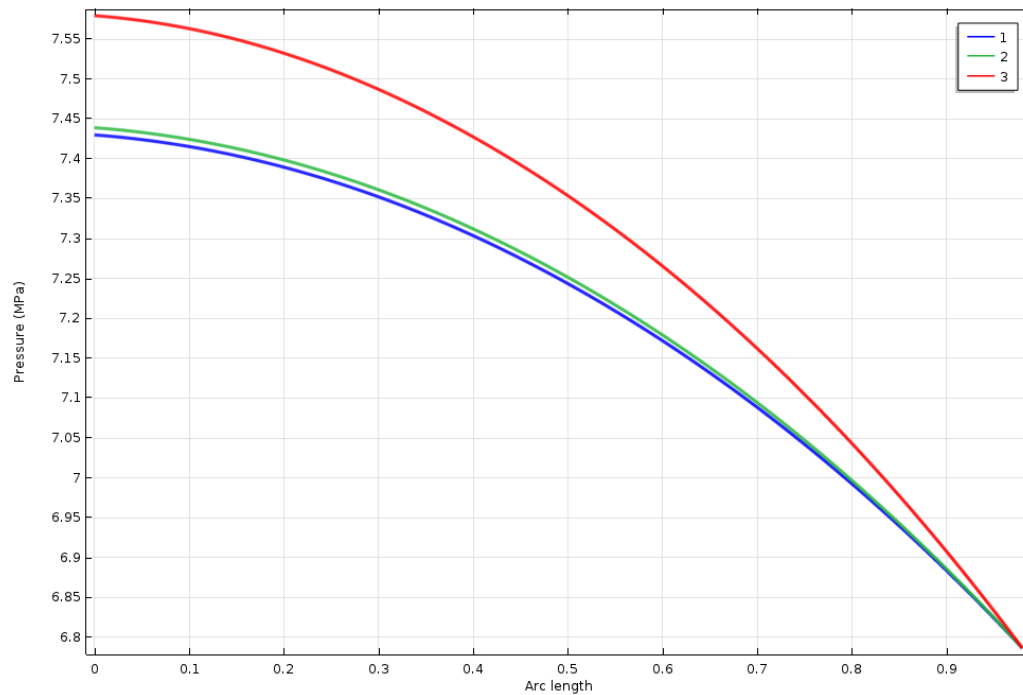


Steady State Surface and Gas Temperature



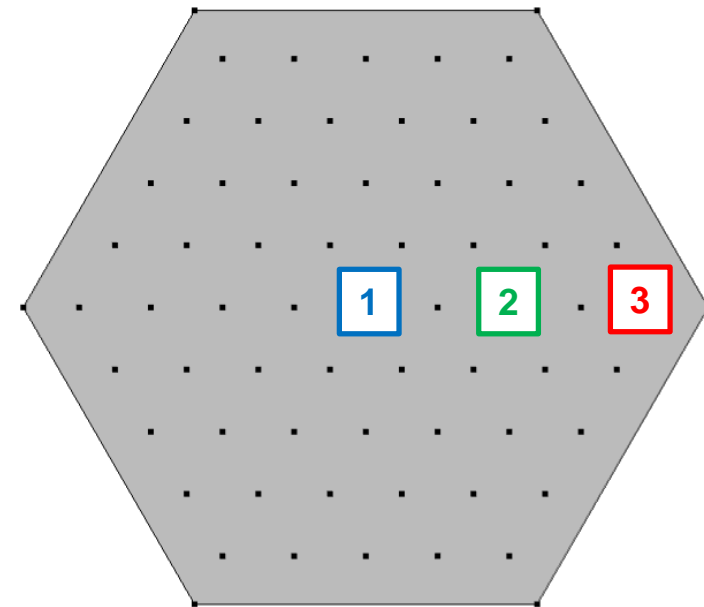
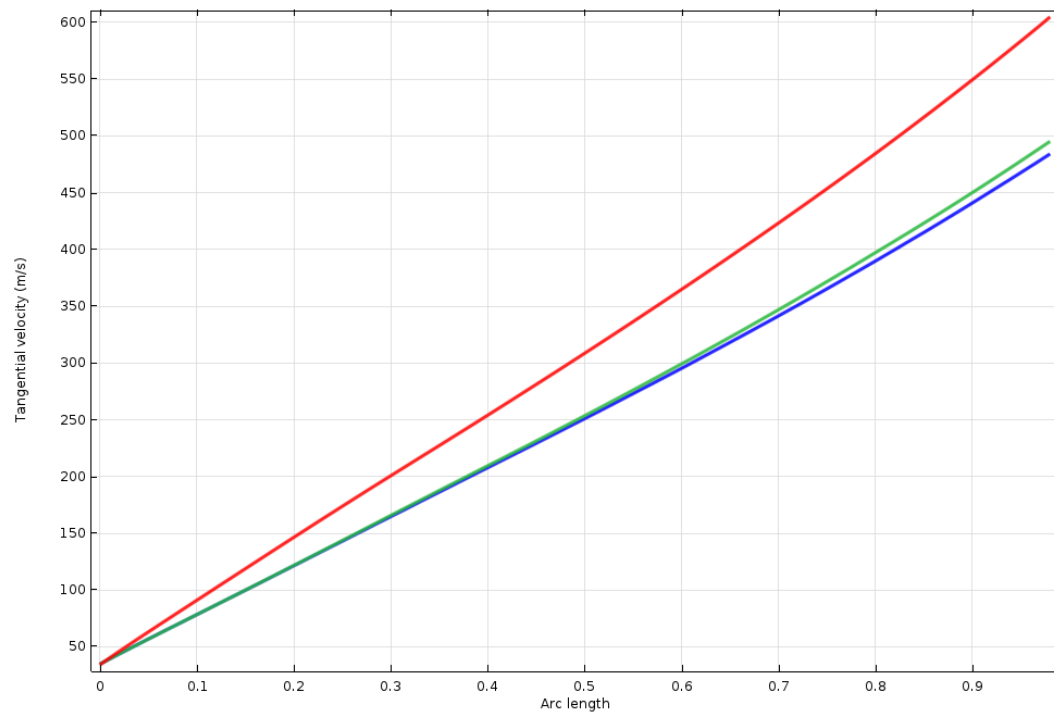
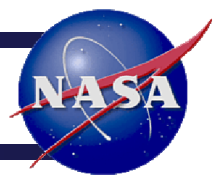


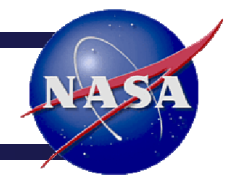
Pressure Drop [Mpa]



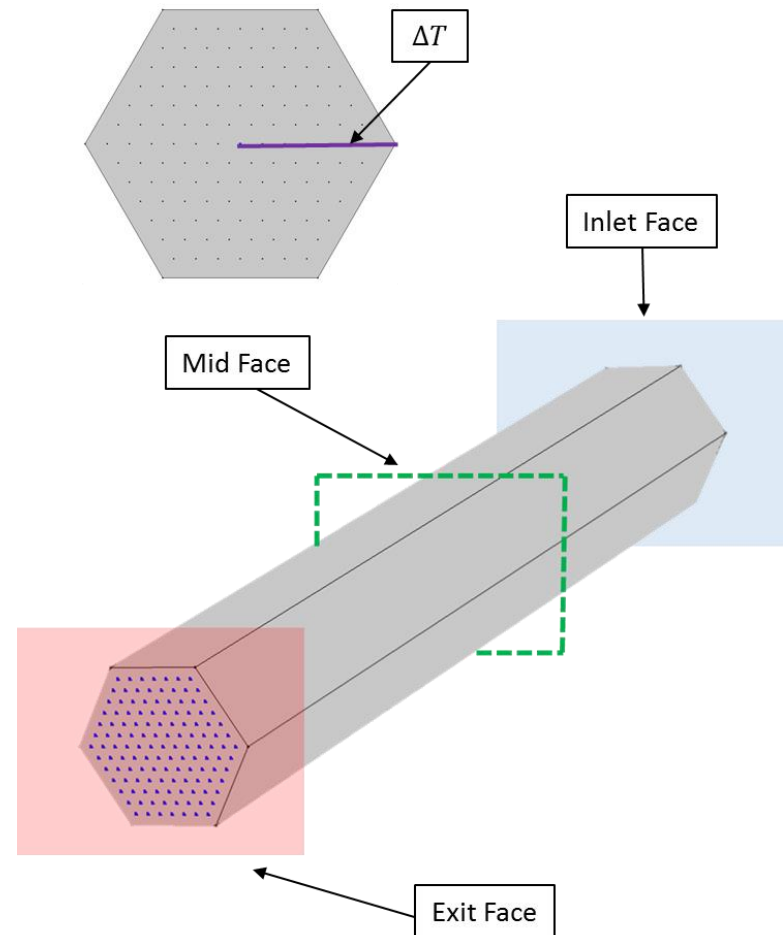
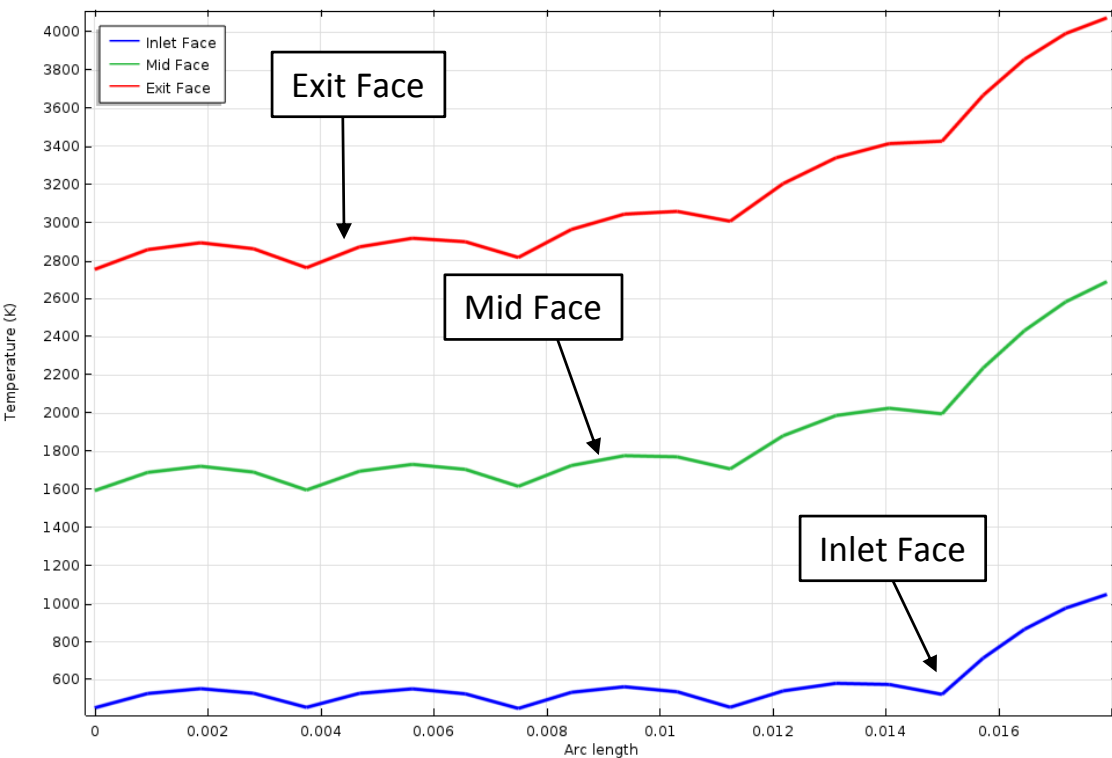


Gas Velocity [m/s]



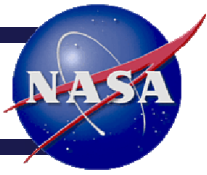


Surface Temperature

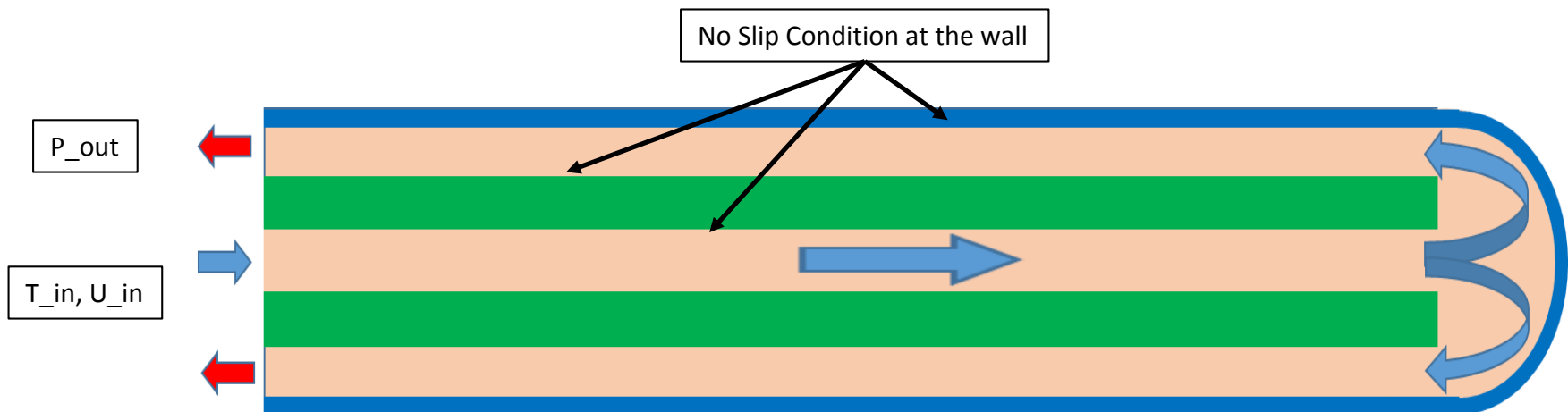




Tie Tube Model

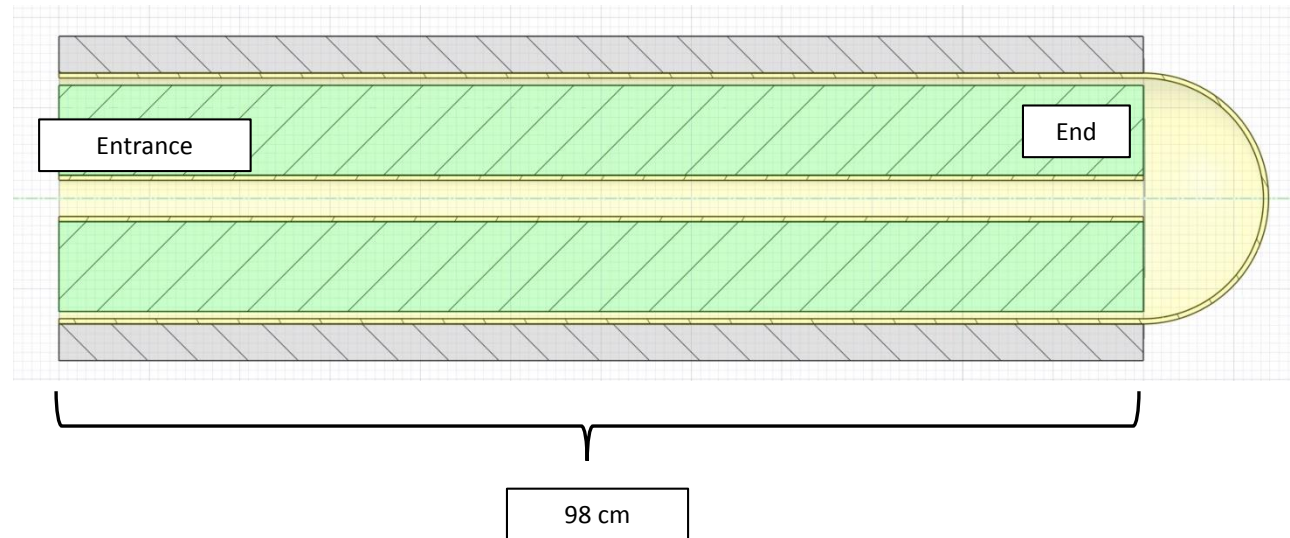
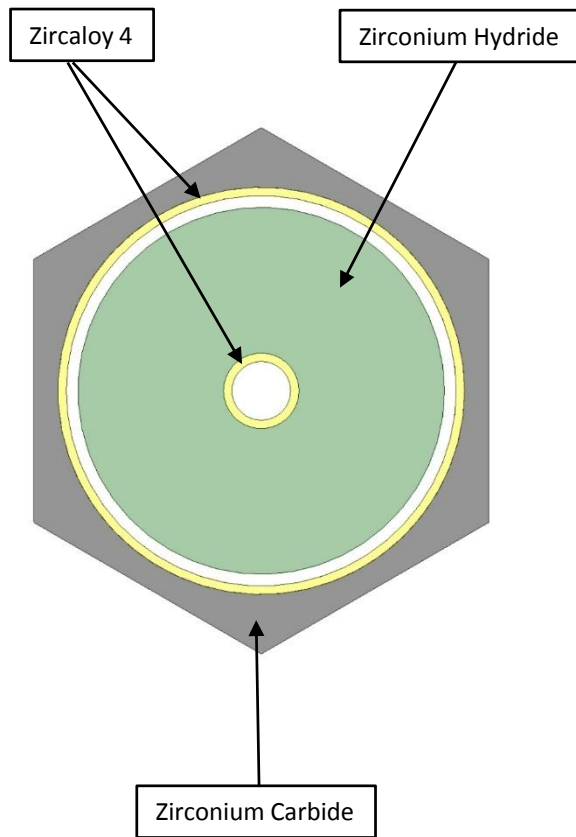


- Created a 2-D axisymmetric transient to steady state model using the CFD turbulent flow and Heat Transfer module in COMSOL
- This model was developed to find and understand the hydrogen flow that might effect the thermal gradients axially and at the end of the tie tube where the flow turns and enters an annulus.



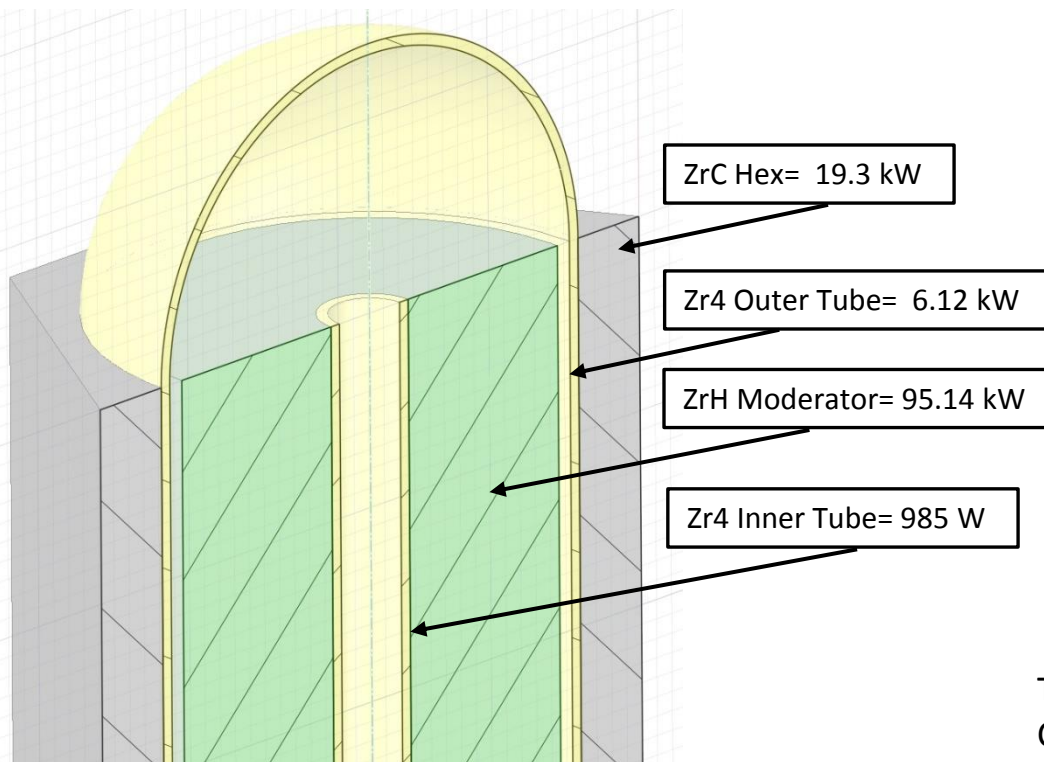
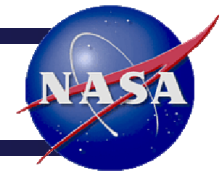


Tie Tube Design





Tie Tube Power

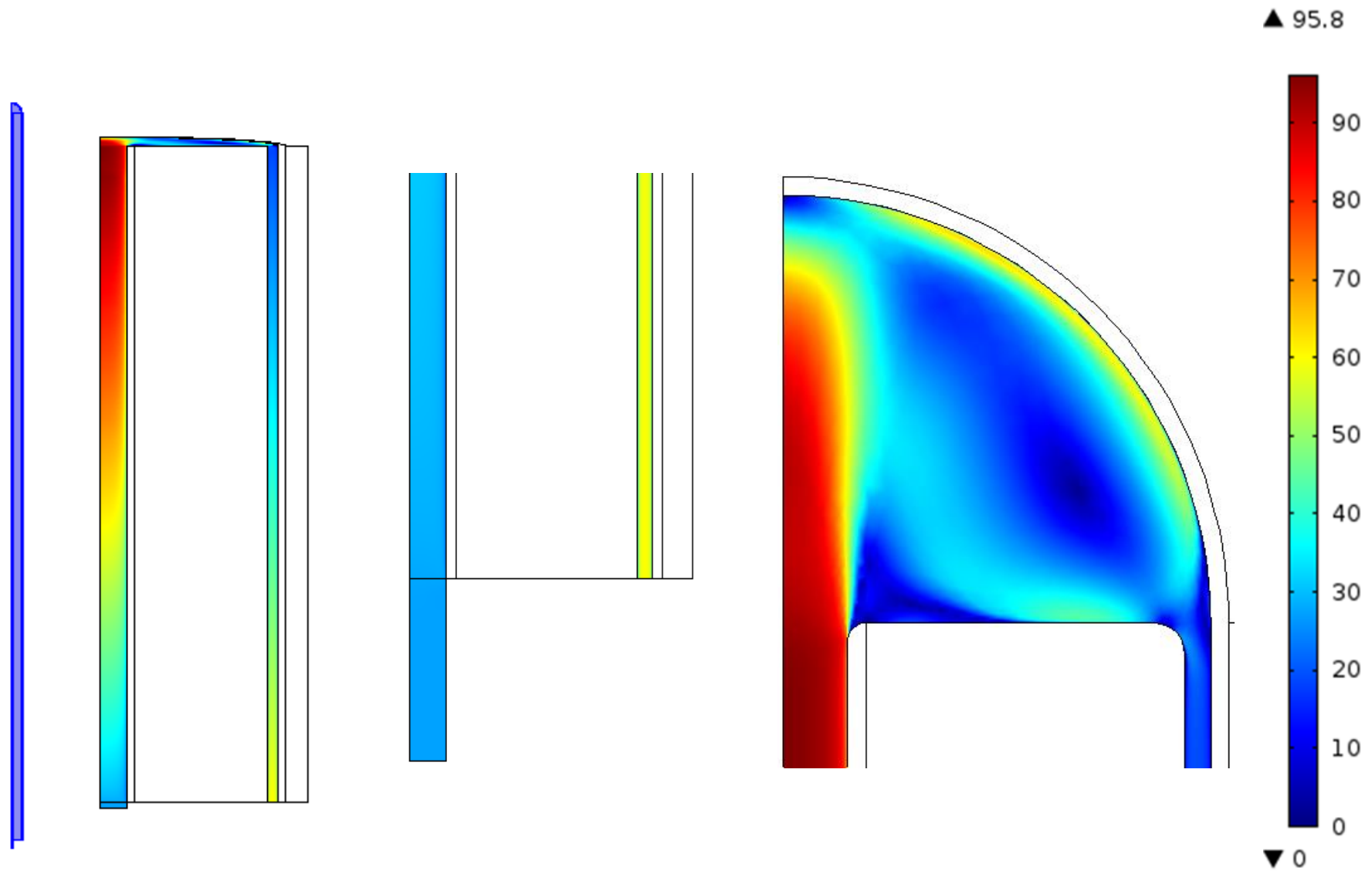
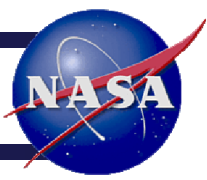


Component	Watts
Fuel Power	692.24[MW]
Zirc4 Inner Power	147.77 [kW]
Zirc4 Outer Power	919.32 [kW]
ZrH Power	14.27[MW]
ZircC Power	2.89 [MW]

This is the total power deposition given by CSNR. The total power for each component was divided by the number of tie tubes.(except the Fuel)

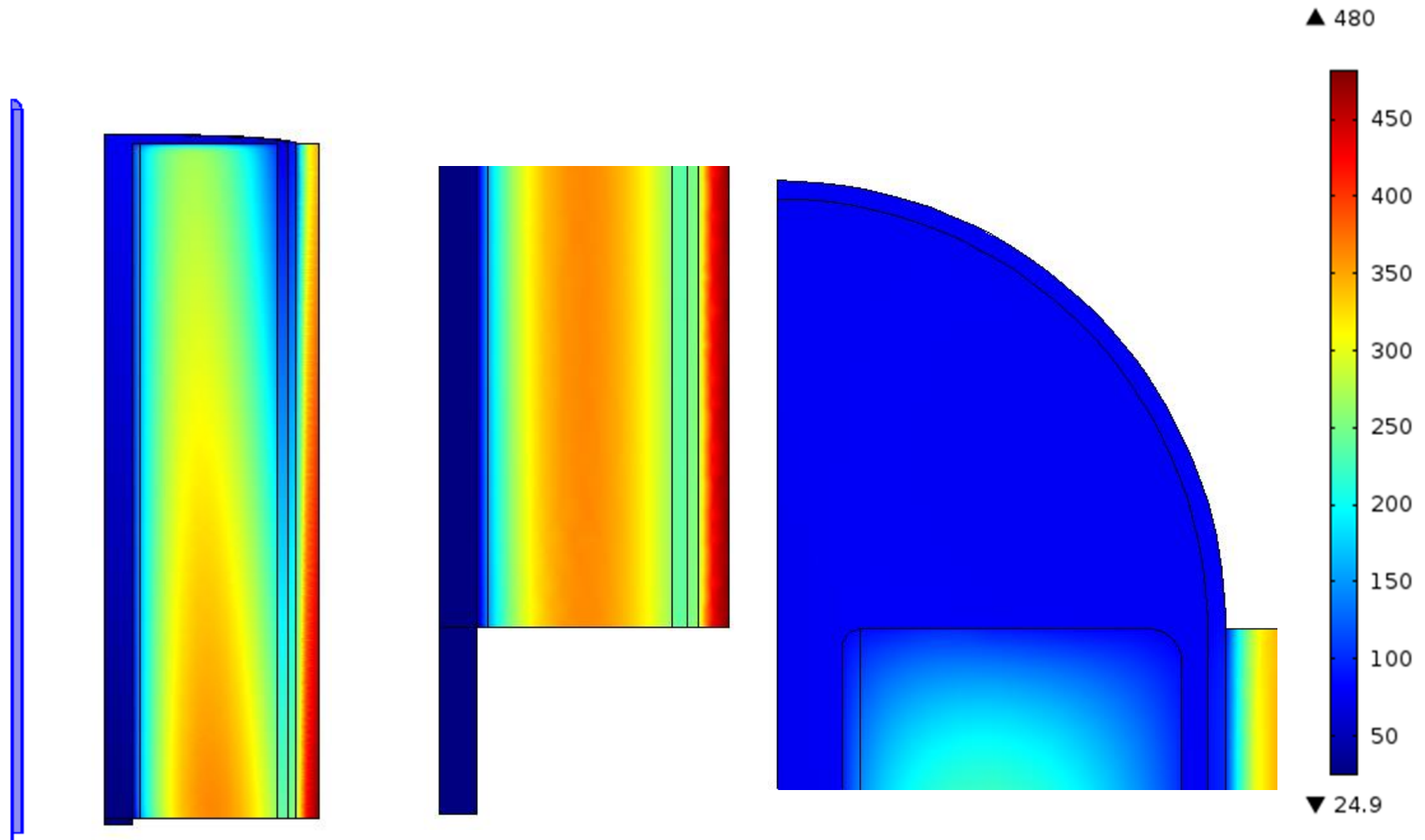


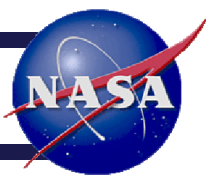
Velocity Profile [m/s]



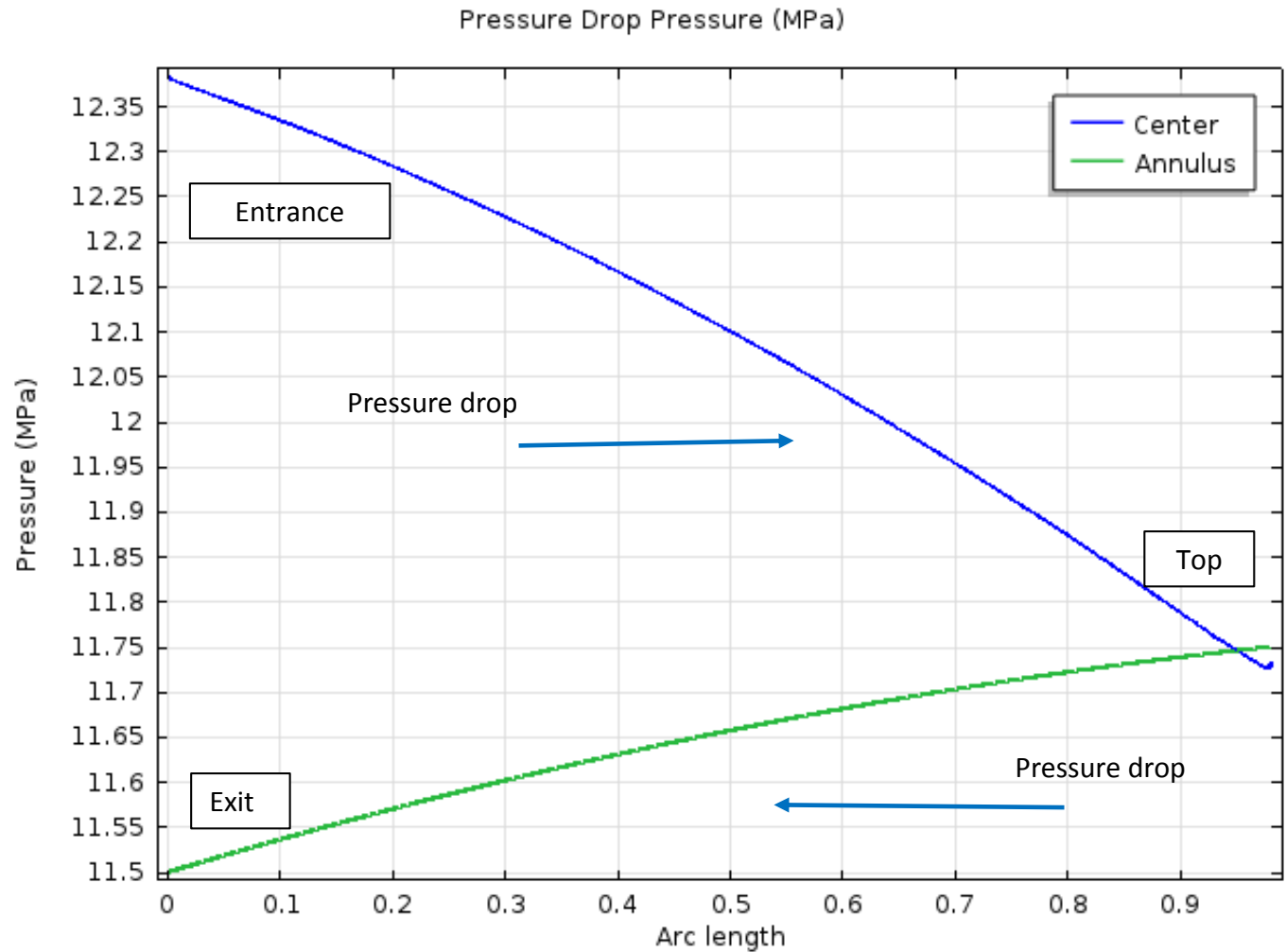
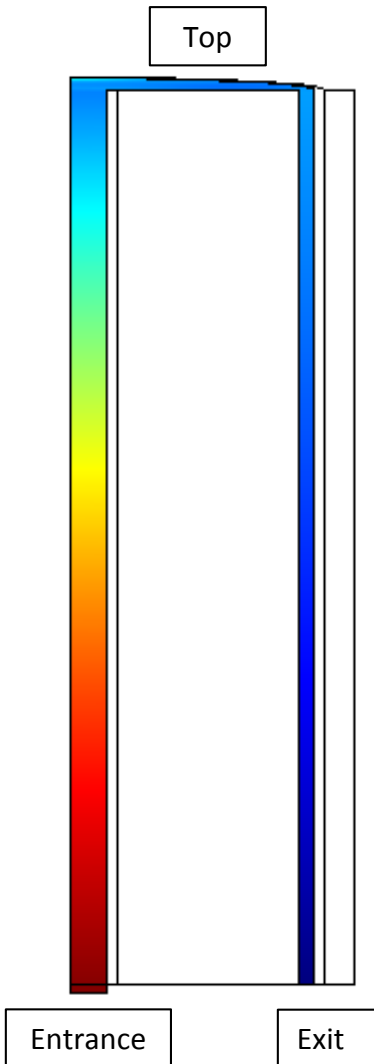


Temperature Profile [K]



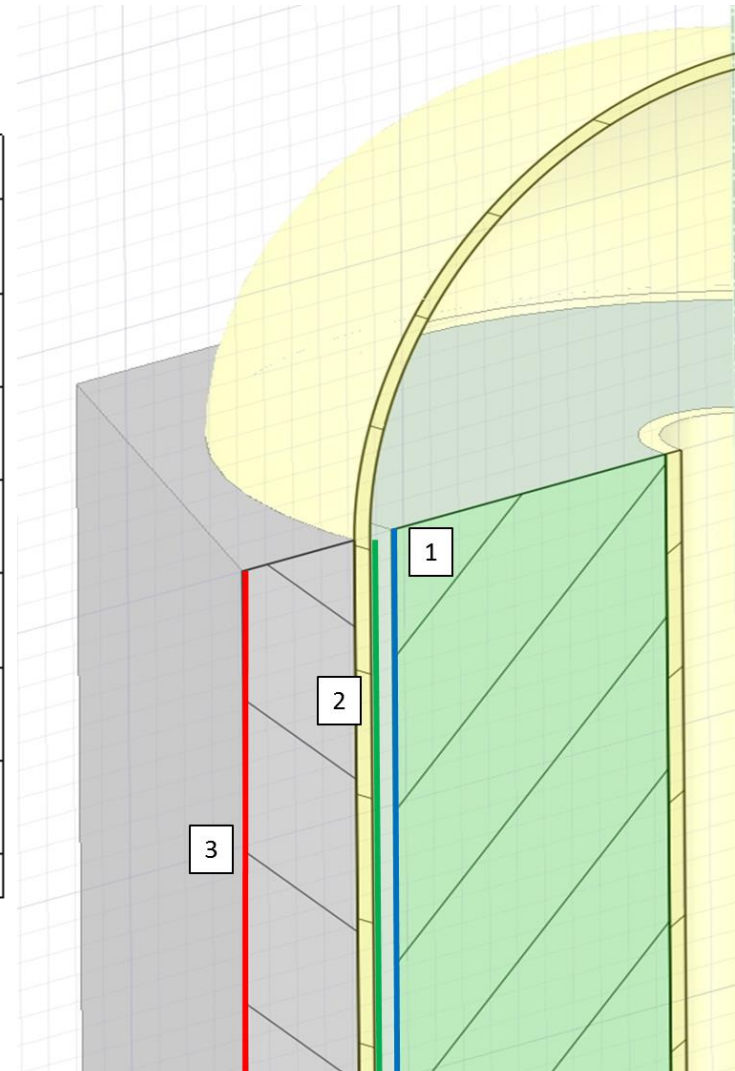
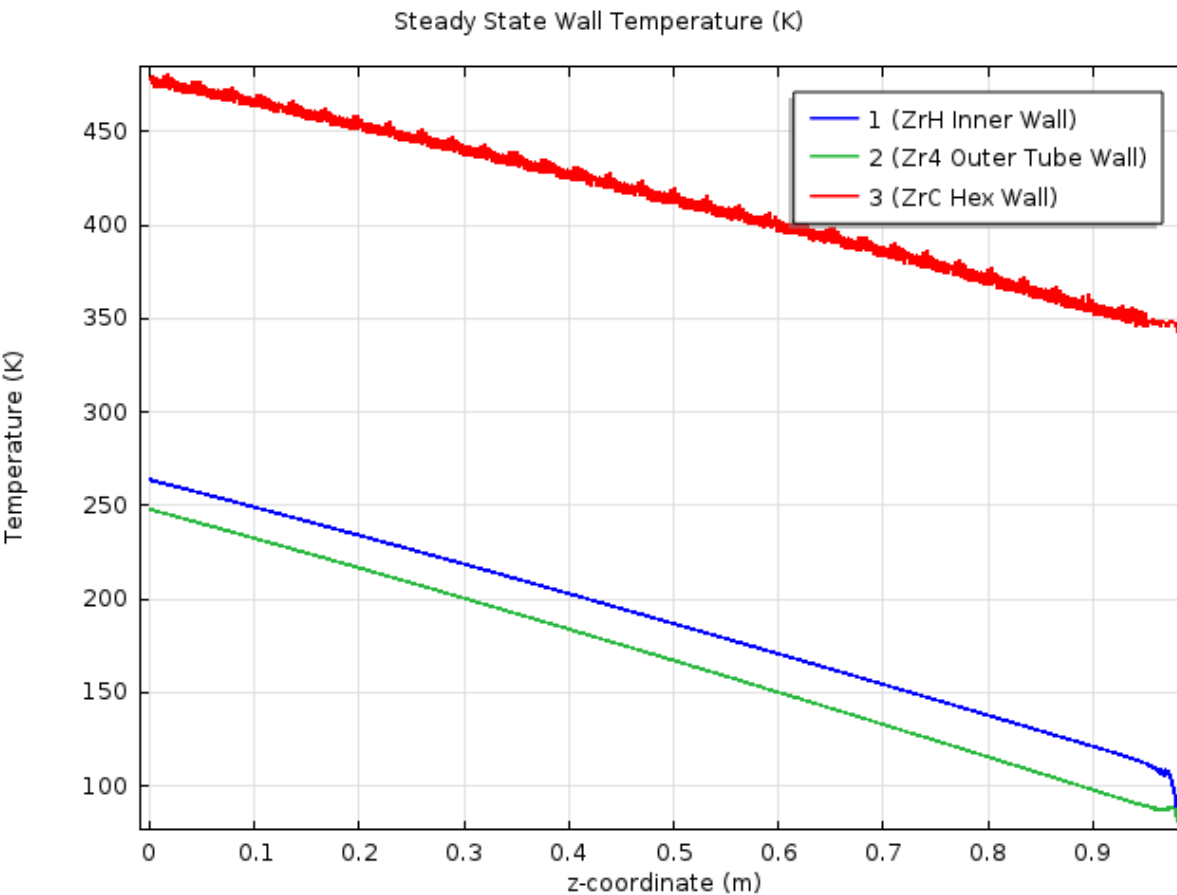


Pressure Drop [MPa]



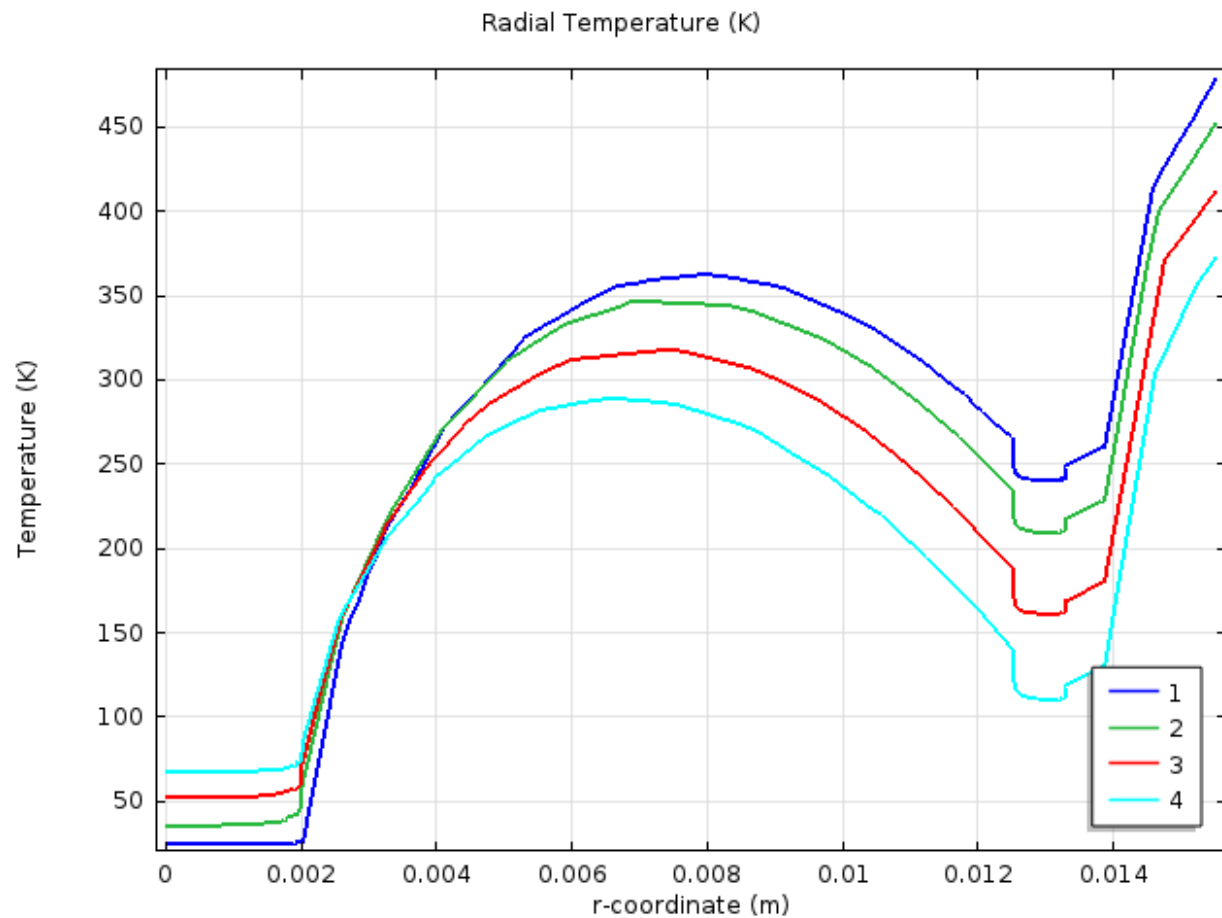
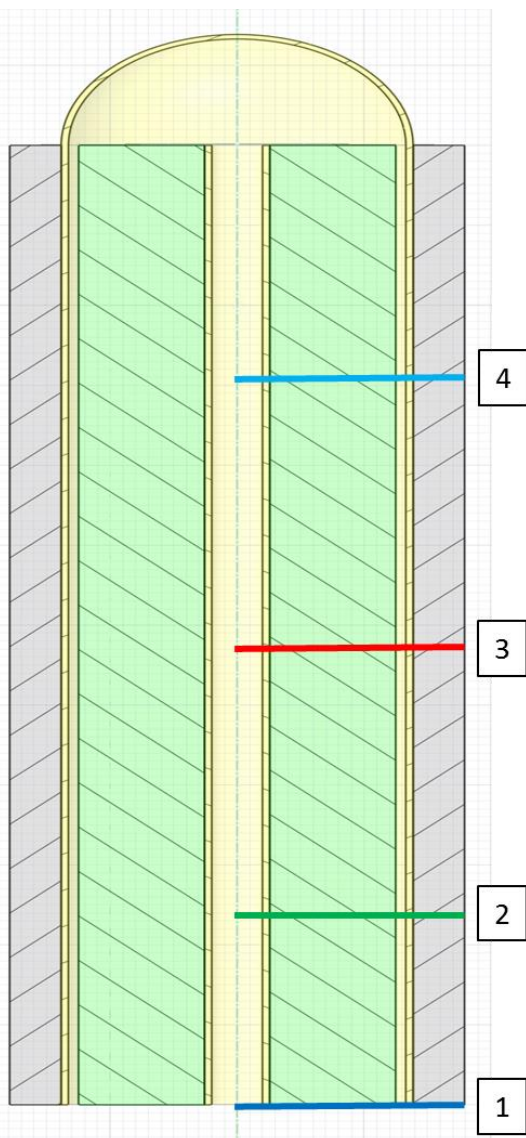
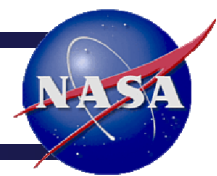


Axial Temperature



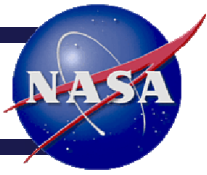


Radial Temperature





Conclusion



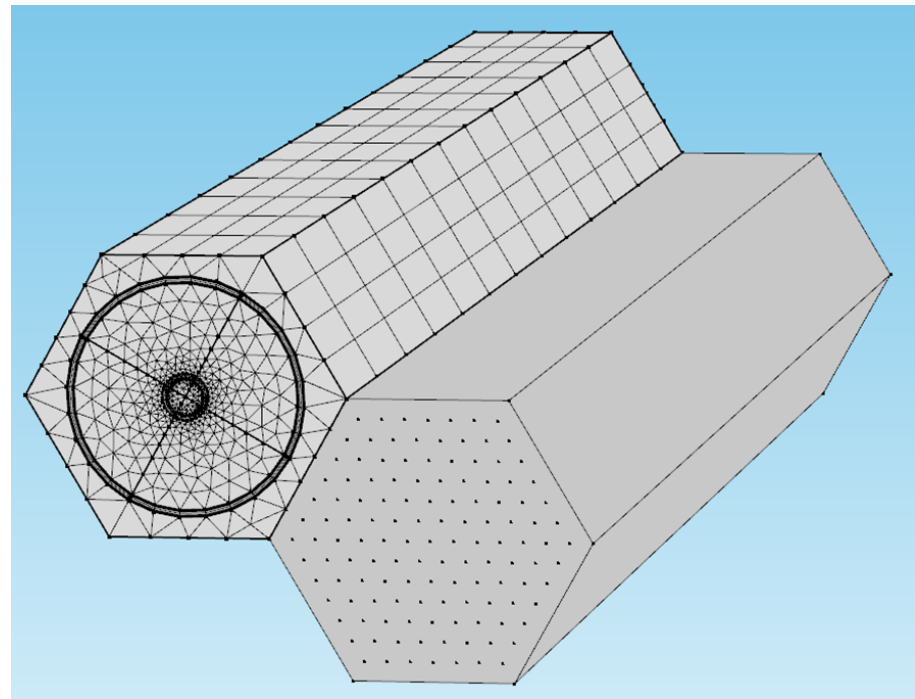
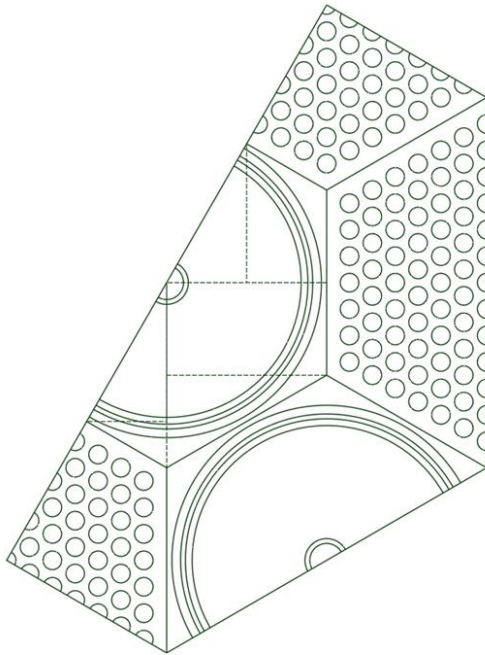
- The Hex fuel rod and Tie tube models were made based on requirements given to us by CSNR and the SCCTE team
- The models helped simplify and understand the physics and assumptions.
- Using pipe correlations reduced the complexity of the 3-D fuel rod model and is numerically more stable and computationally more time-efficient compared to the CFD approach.
- The 2-D axisymmetric tie tube model can be used as a reference “Virtual test model” for comparing and improving 3-D Models.



Future Work

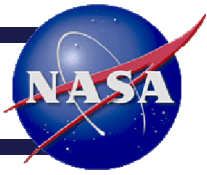


- Continue developing a full 3D model which combines the hex fuel rod and tie tube mated flat to flat.
- Understand and iterate contact resistance between mating surfaces.
- Add axial power variation for both hex fuel rod and tie tube





Questions



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